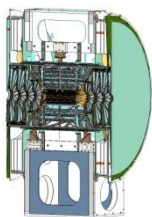


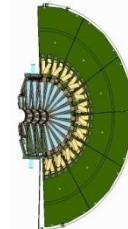
# Mechanics and Assembly of the Silicon Vertex Detector for **PHENIX**

Walter Sondheim - *LANL*

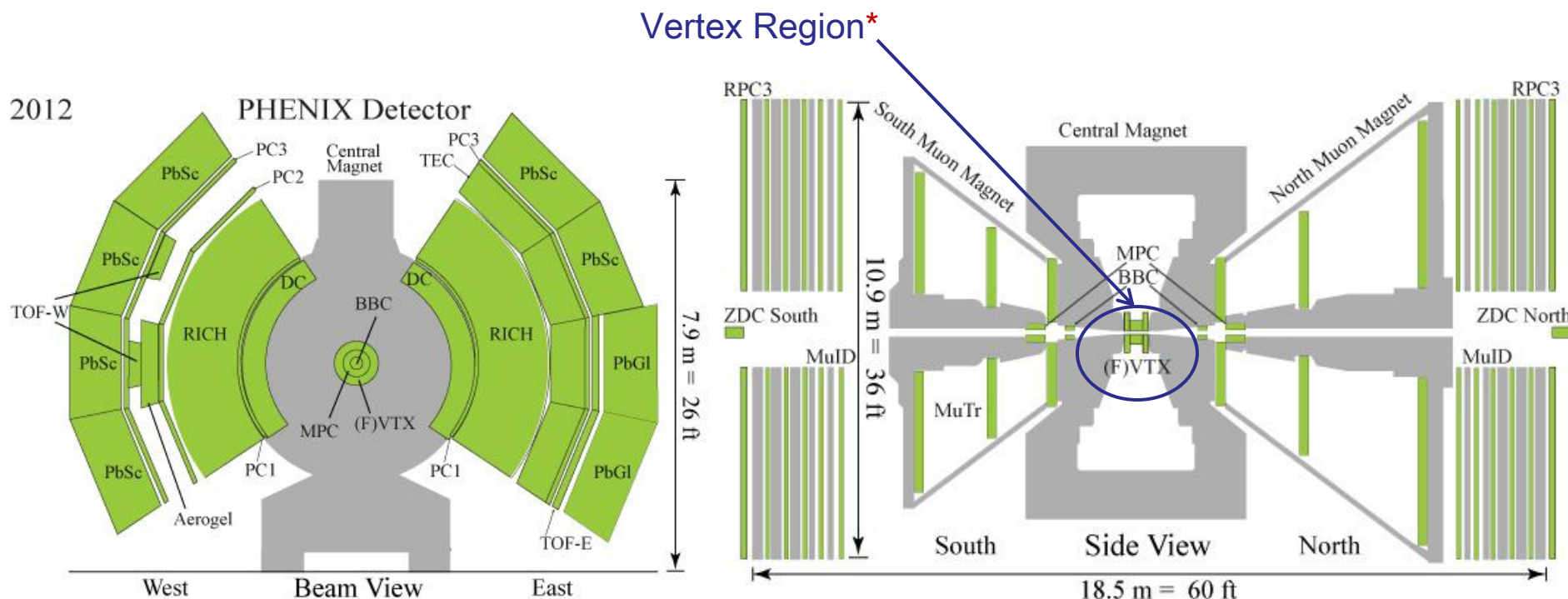
Mechanical Project Engineer; VTX & FVTX  
Detectors



# PHENIX Experiment at RHIC:



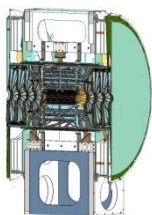
The **PHENIX** experiment at **RHIC** is now in its **11<sup>th</sup>** year of data taking. Experimental configuration for RUN in 2012:



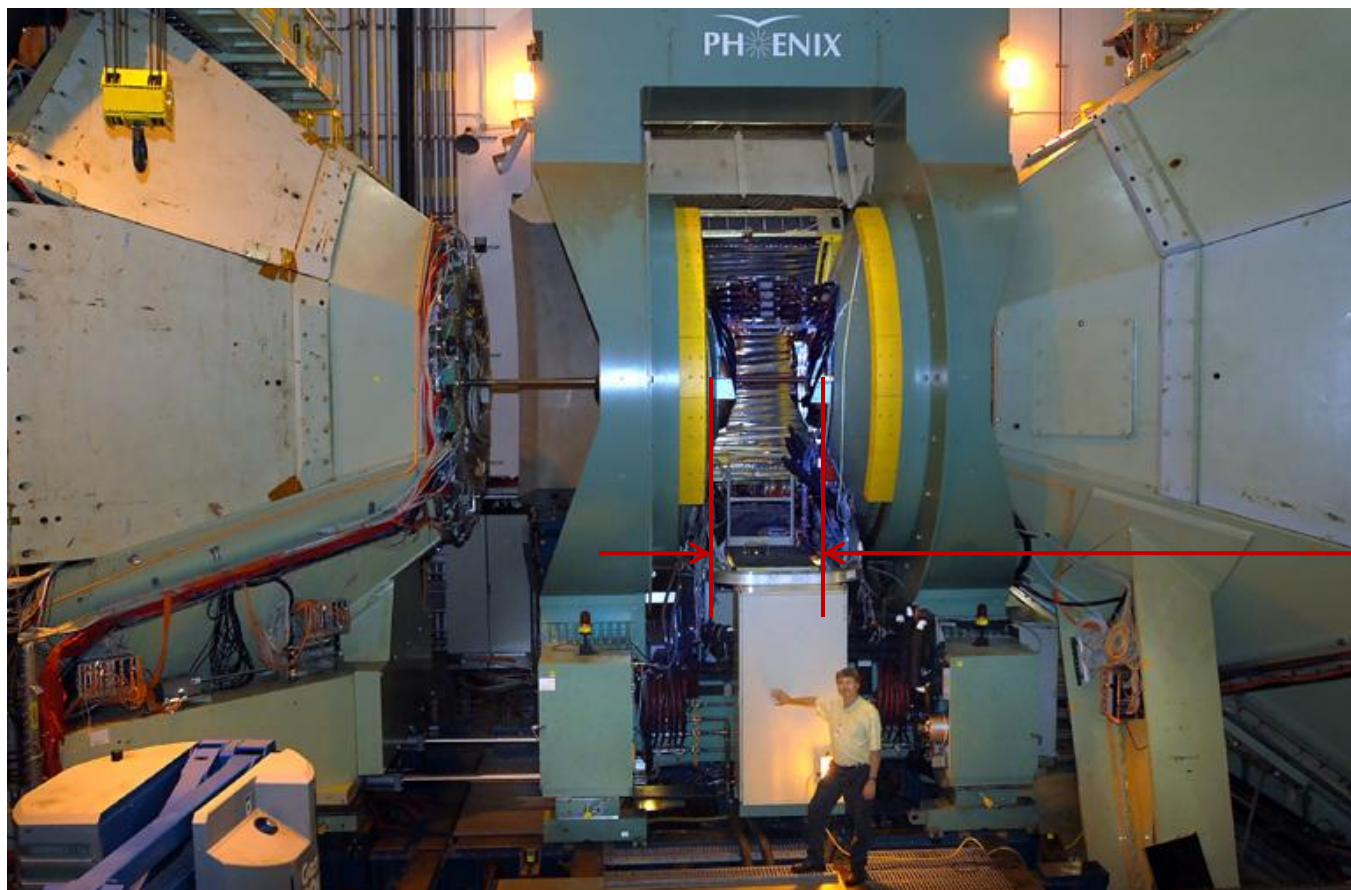
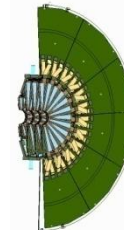
2 central arms; electrons, photons, hadrons

2 muon-spectrometer arms; muons

\*VTX installed for current run cycle, FVTX next year's run cycle

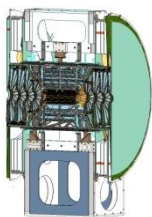


# PHENIX Experiment at RHIC:

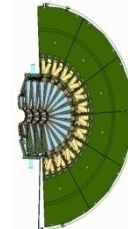


800.0 mm

Available space for Vertex Detector 800.0 mm between the Central Magnet pole tips along the beam axis. The original 3.0 inch diameter Beryllium beam pipe was replaced with a 1.575 inch ID x .020 wall NEG coated Beryllium beam pipe, now installed for this run cycle.

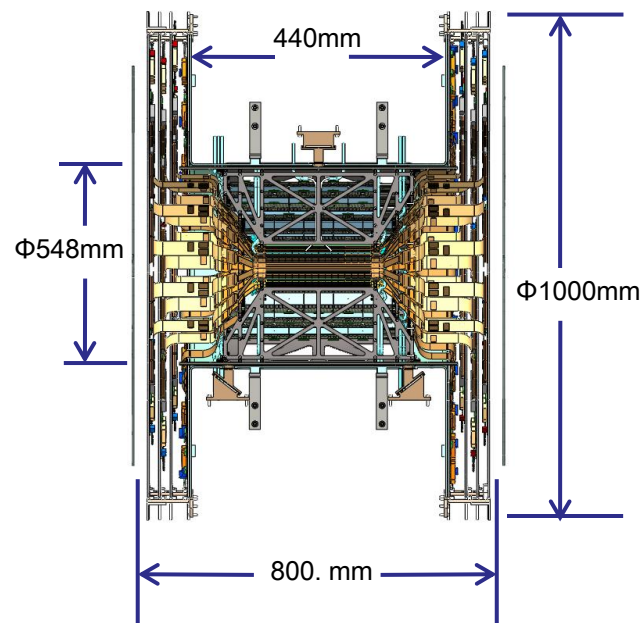


# VTX Design Criteria:

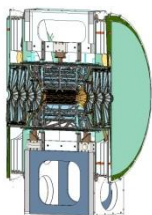


## VTX - Barrel Detector:

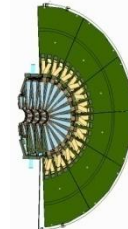
- 2 pixel sensor layers at a radius = 25.0 and 50.0 mm
  - Fine granularity, low occupancy
    - 50 $\mu$ m x 450 $\mu$ m pixel size, ALICE LHCB1 read-out chip
    - AC Coupled read-out, required coolant temp. @ 10°F
      - » To prevent de-lamination
- 2 stripixel layers at a radius = 100.0 and 140.0 mm
  - Unique sensor design from BNL Instrumentation
    - 80 $\mu$ m x 1000 $\mu$ m pixel pitch, SVX4 read-out chip
    - DC Coupled read-out, required cooling @ 0° F,
      - » Avoid increase leakage current from radiation damage
- $\Phi$  acceptance  $\sim 2\pi$
- $|\eta|$  acceptance  $< 1.2$
- Dimensional structural stability to 25 $\mu$ m



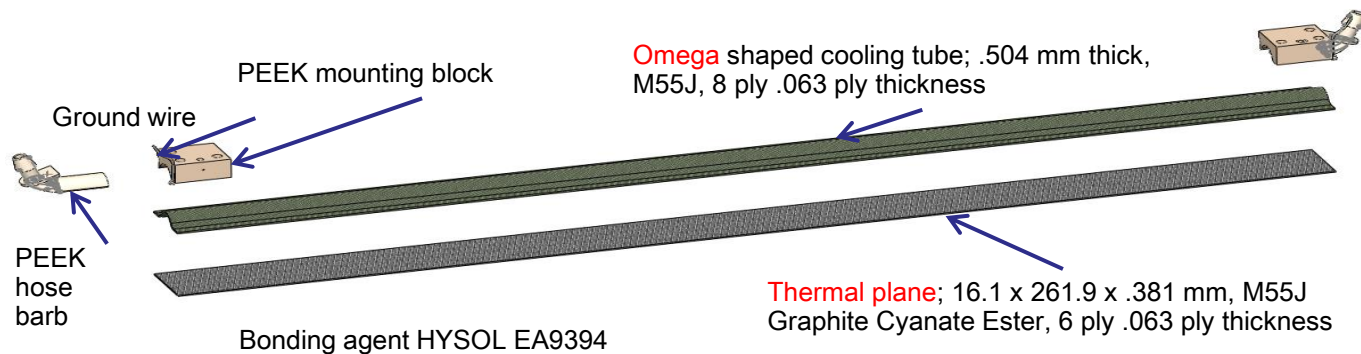




# VTX - Pixel layers 1 and 2:



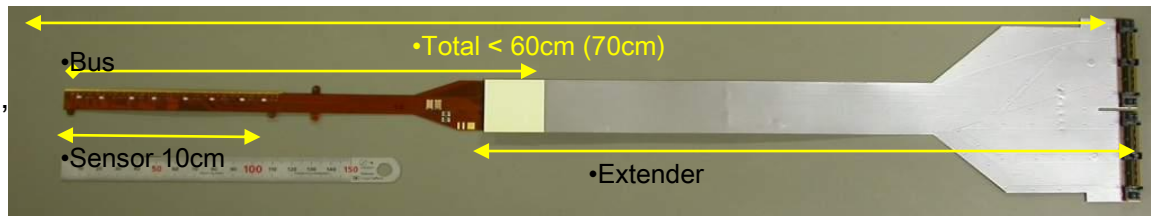
- Closest sensors to beampipe, radiation length should be kept to a minimum
  - Stave design uses Carbon composite technology, Omega shaped bonded to backside of thermal plane to create cooling channel. Bonded assembly must meet mechanical tolerance for flatness of 100. microns prior to bonding of sensor modules
  - Layers 1 & 2; 4 sensor modules per ladder, Layer 1 - 5 ladders layer 2 - 10 ladders per half barrel

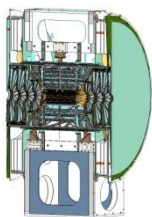


**Assembled pixel stave:** stave + sensors + readout chips + bus, readout is split in half – left bus and a right bus

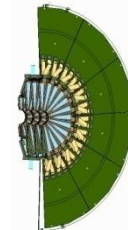


**Assembled pixel stave** with bus extender attached, interface with SPIRO readout card



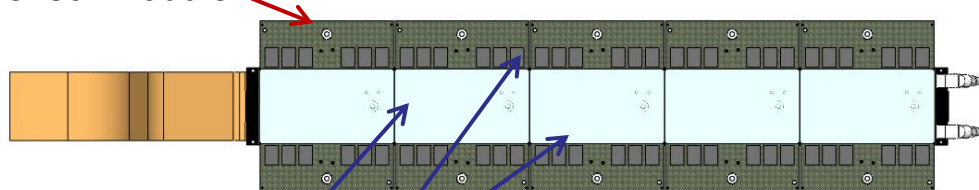


# VTX - Stripixel layers 3 and 4:

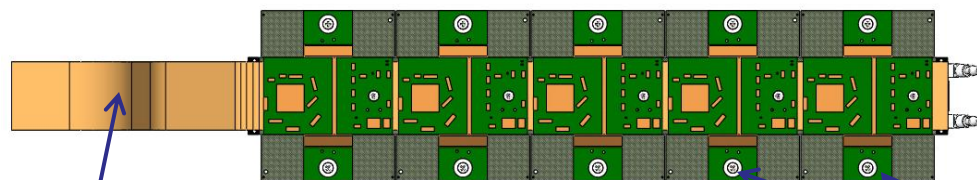


- Improve track segment construction
  - BNL sensor design provides 2 dimensional, single sided readout
  - Readout uses FNAL's SVX4 chip; 128 channels per chip, 340K channels for layers 3 & 4
  - Layer 3; 5 sensor modules per ladder, 8 ladder assemblies per half barrel
  - Layer 4; 6 sensor modules per ladder, 12 ladder assemblies per half barrel

Sensor Module

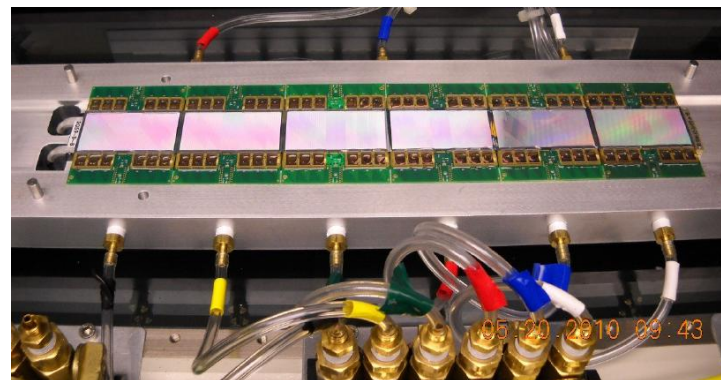


Sensors  
SVX4 chips

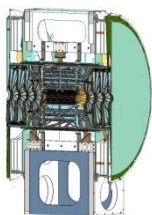


Readout bus

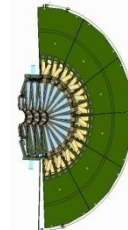
Interconnection between top layer and bus layer using PariPoser material



Layer 4 stave with sensor modules being located on stave using vacuum tooling, prior to bonding



# Stripixel stave construction:

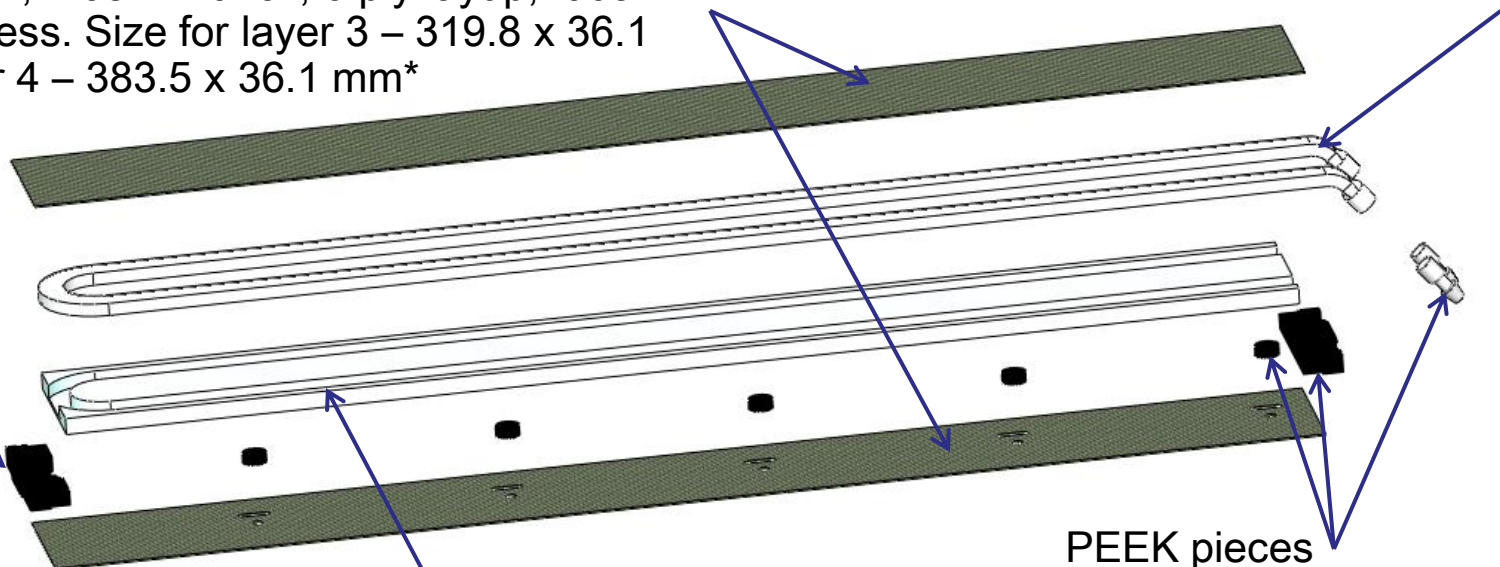


**Layer 3 & 4 stave assembly:** designed to allow for individual electronic modules and bus to be mechanically attached to stave backside – not bonded.

Face Sheets; K13D2U with EX1515 Cyanate Ester resin, .408mm thick, 6 ply layup, .063 ply thickness. Size for layer 3 – 319.8 x 36.1 mm, layer 4 – 383.5 x 36.1 mm\*

Aluminum rectangular cooling tube; 3.18 x 6.35 x .38 wall (mm)

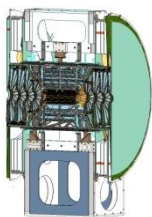
Aluminum end-block, grounds cooling tube



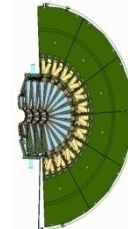
Carbon Foam Core; Allcomp K3, 4.2mm thick

Bonding agent HYSOL EA9396

\*Layer 3 stave shown in exploded view, assembly flatness tolerance 100. microns



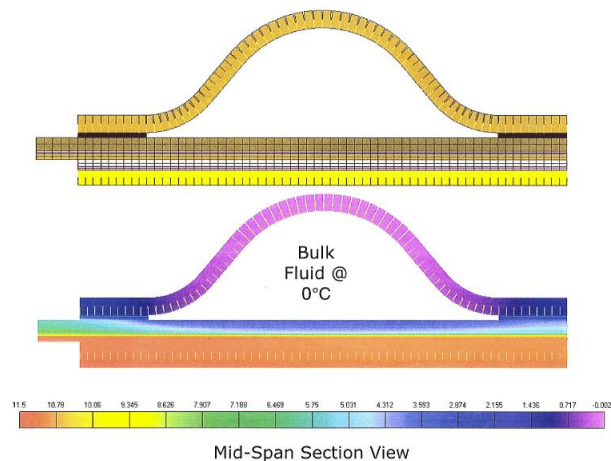
# Thermal/Mechanical analysis:



## •Pixel stave analysis

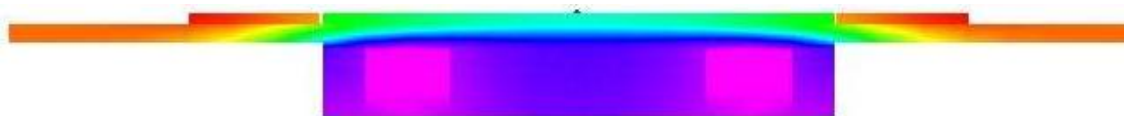
- Thermal load for pixel stave is 19.50 watts
- Each ladder's mass summary:
  - Structure/Si-detector/Readout chips 16.4 grams
  - Coolant: 6.5 grams (3M-NOVEC 7200)
  - Total: 23.0 grams
  - $\Delta T: 11.5^\circ\text{C}^*$ 
    - $23.^\circ\text{C}$  with a tube
  - Gravity sag < 2. microns
  - Pressure tested

\*Calculations using Nastran- Mat9 software

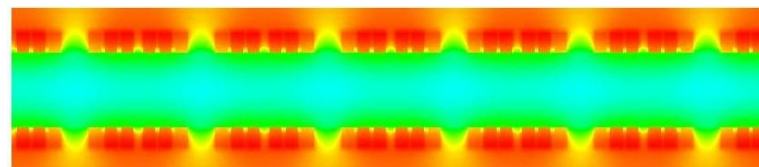


## •Stripixel stave analysis

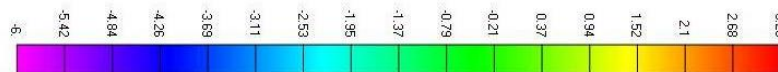
- Design goal to keep DC coupled sensors at  $0^\circ\text{C}$ :
  - Coolant wall temperature at  $-6^\circ\text{C}$
  - Peak temperature  $3.2^\circ\text{C}$
  - Temperature rise between coolant and sensor  $5.55^\circ\text{C}$



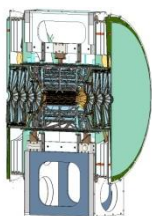
Cross section Temperature profile, layer 4 ladder



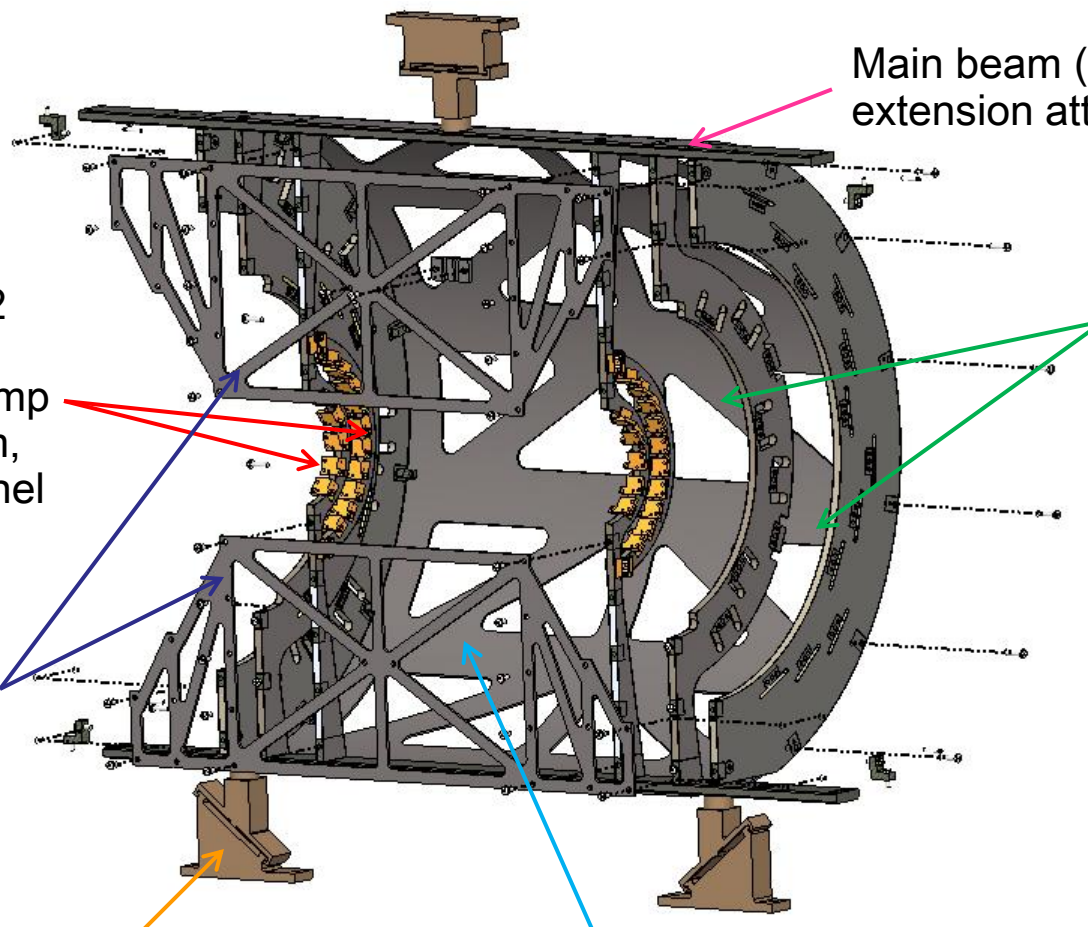
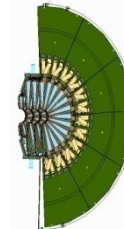
Surface temperature, layer 4 ladder







# Space-frame and Barrel Mounts, exploded view:



**Pixel** layer 1 & 2  
barrel mounts,  
M55J and Allcomp  
K3 Carbon foam,  
3.6mm thick panel  
assembly

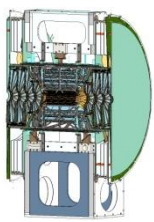
**Center gussets**  
CN60 cloth,  
2.0mm thick

Space-frame flexure,  
1 of 3 on each half

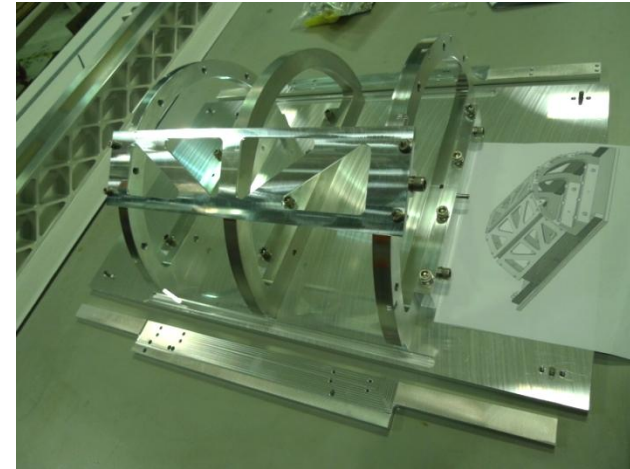
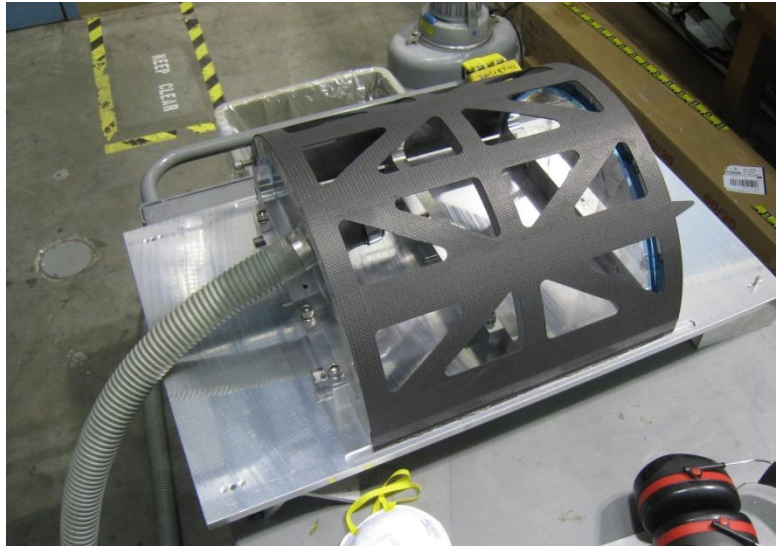
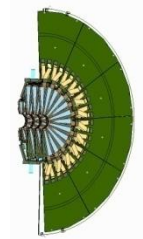
Main beam (2), POCO Graphite,  
extension attaches FVTX detector

**Stripixel** layer 3 & 4  
barrel mounts, M55J  
and Allcomp K3  
Carbon foam, 6.3mm  
thick panel assembly

**Space frame shell**, CN60  
cloth with EX1515 resin,  
1.5mm thick

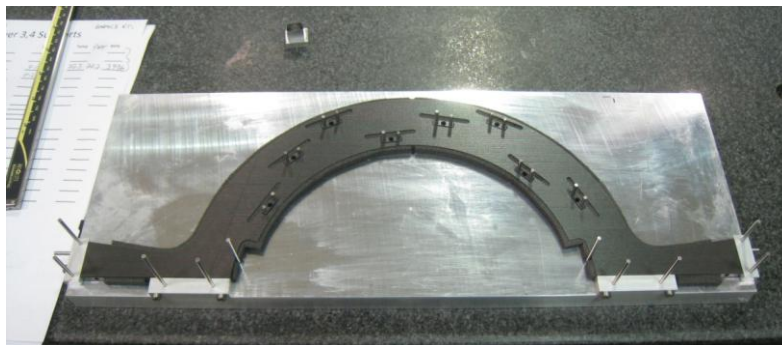


# Space-frame component fabrication and assembly:



Space-frame shell tooling

Space-frame shell: Vacuum jig machining cut-outs



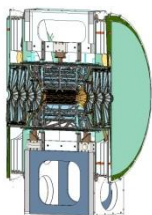
Layer 4 barrel mount on assembly jig



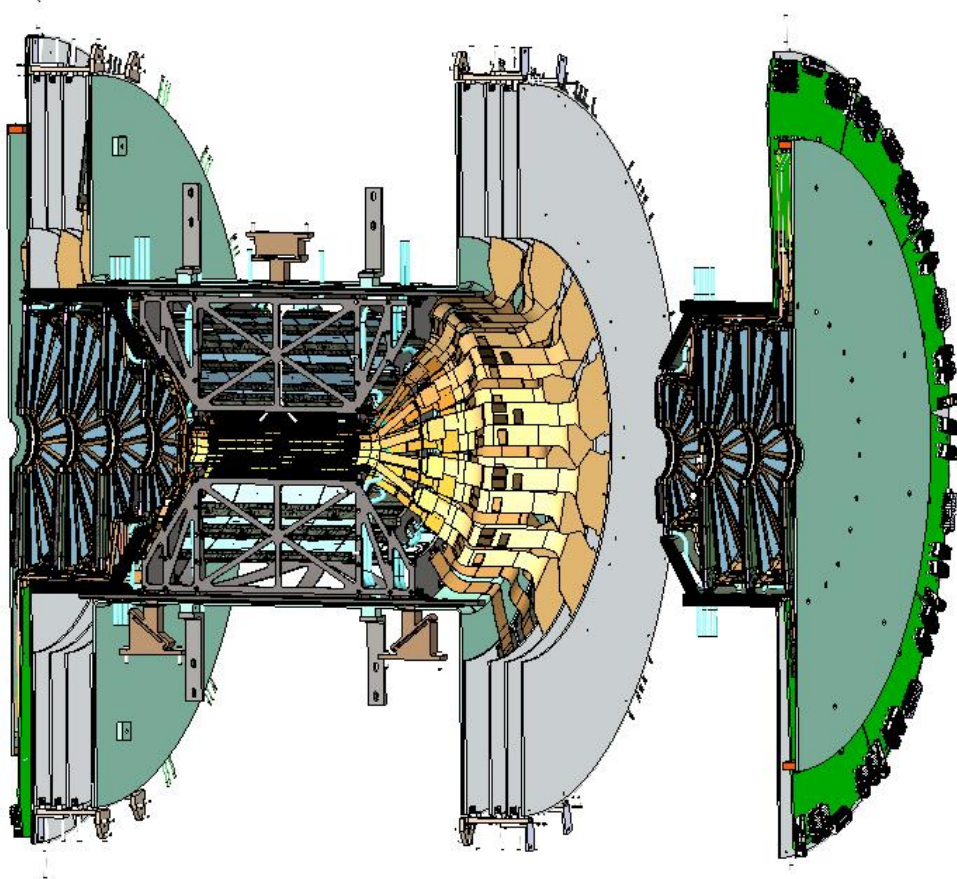
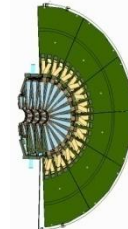
Layer 2 barrel mount on assembly jig

All work at LBNL Composite Shop



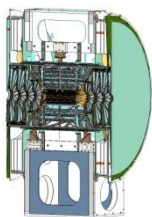


# FVTX detector:

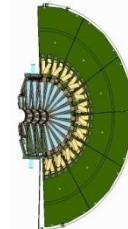


- Silicon tracking in the forward regions of PHENIX;
  - $1.2 < |\eta| < 2.4$
  - $\Phi$  acceptance =  $2\pi$
- Each FVTX assembly;
  - 4 tracking stations (**Disks**)
    - Silicon mini-strips, 2.8 – 11.2mm
    - 75. micron pitch (radial direction)
    - FPHX readout chip (FNAL design)
    - ~1.1M channels of readout

FVTX detector exploded view from VTX assembly



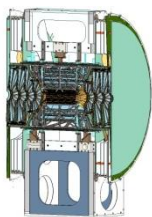
# FVTX Station Disks:



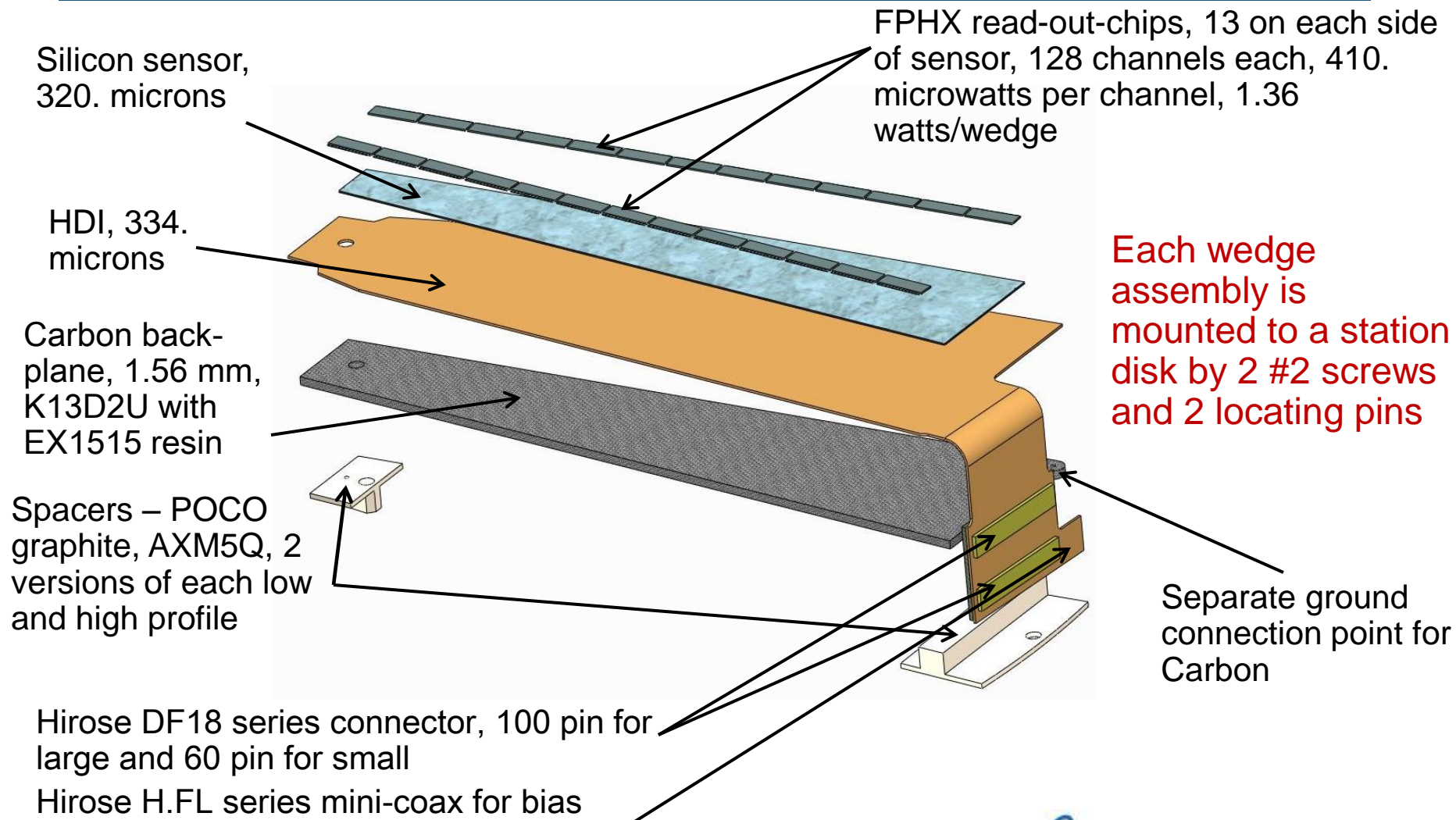
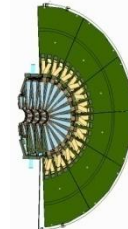
- View of a **Station Disk** assembly with large **Wedges** attached to both sides
- Each **Wedge** covers 15 degrees, each sensor covers 7.5 degrees, **Wedges** on both sides of **Disk** staggered by 7.5 degrees front to back – hermetic coverage in phi
- Each **disk** assembly is pressure tested to 30. psi, cycled 5 times
- The **disk** assembly bonding agent was Hysol EA9396

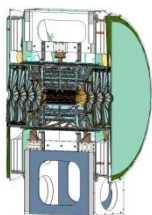




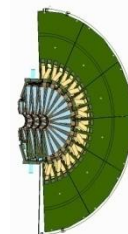


# Large **Wedge** construction:



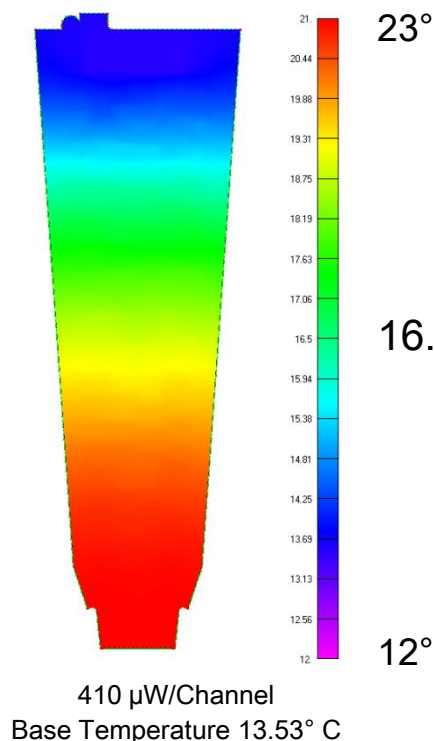


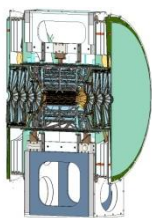
# Large **Wedge** analysis:



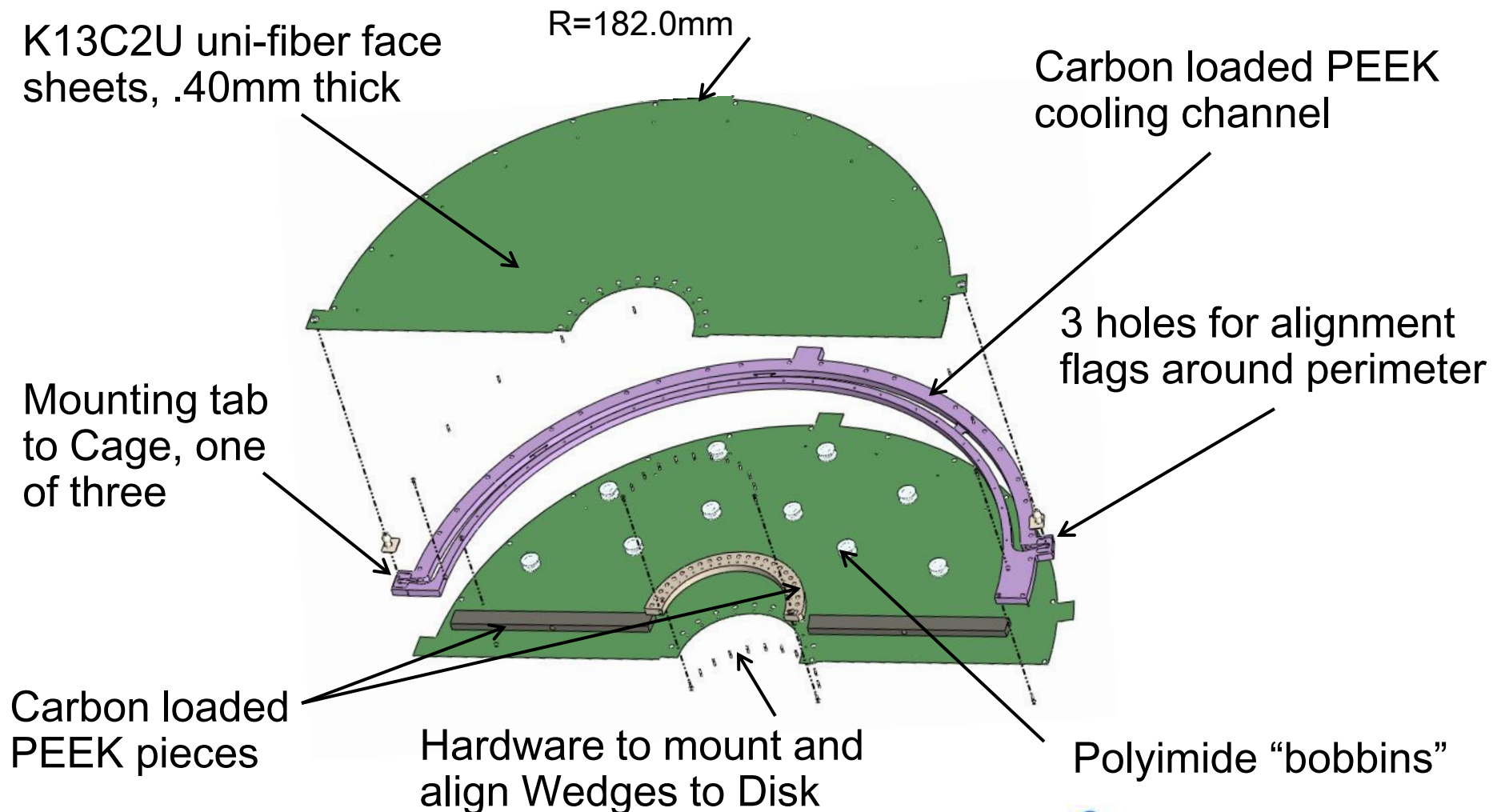
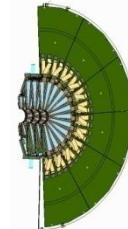
## • Thermal path for heat generated on large **Wedge**

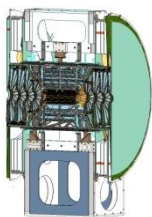
- Delta T on large **Wedge** is ~7.47 degrees C
- Heat from FPHX chips passes through HDI into Carbon backplane – through POCO graphite thermal block to **Station Disk** where coolant flows around perimeter – NOVEC 7200 coolant
- Delta T from **Disk** to **Wedge** ~ 8. degrees C
- In analysis a temp constraint was set to keep peak FPHX chip temp at 21 degrees C
- Bonding of all elements of **Wedge** assembly, made using Arclad 7876 transfer adhesive, 50. micron thick



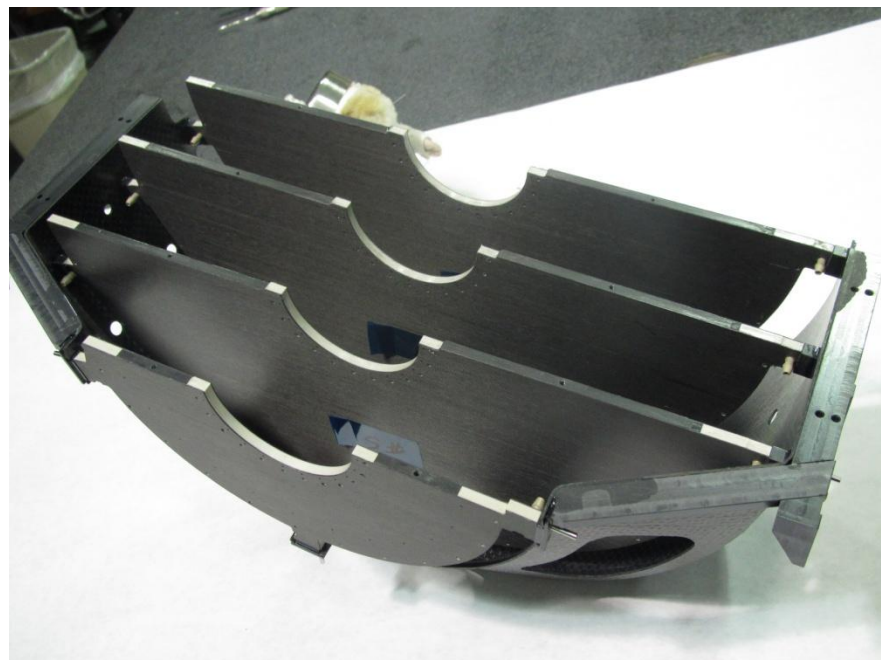
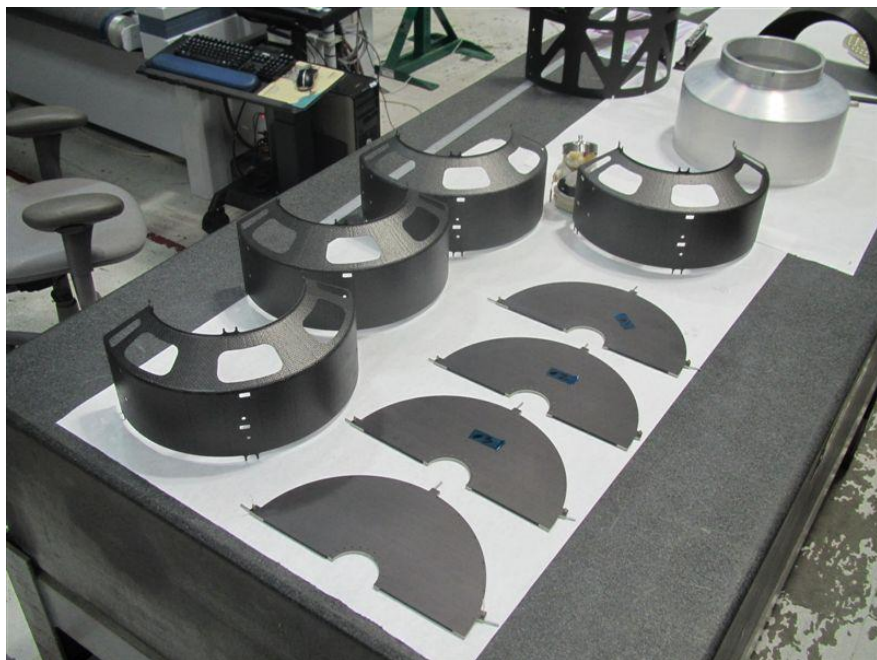
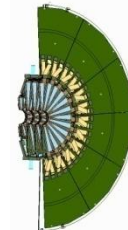


# Station Disk construction, Stations 2, 3 & 4 Large Disk:



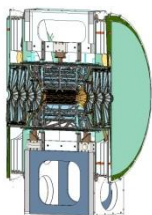


# FVTX construction:

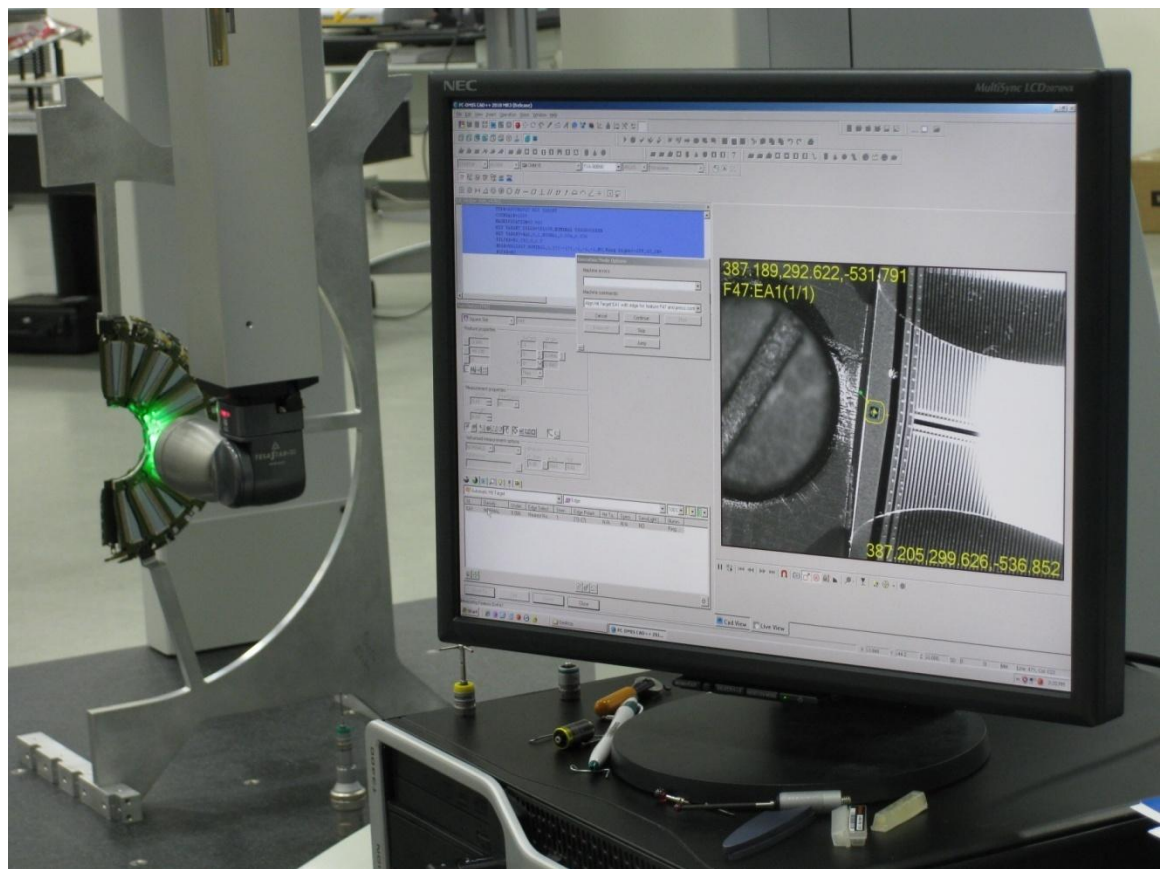
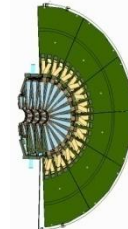


- FVTX cages and station disks being fabricated, tested and assembled at the LBNL composite shop.

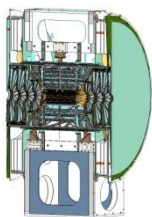




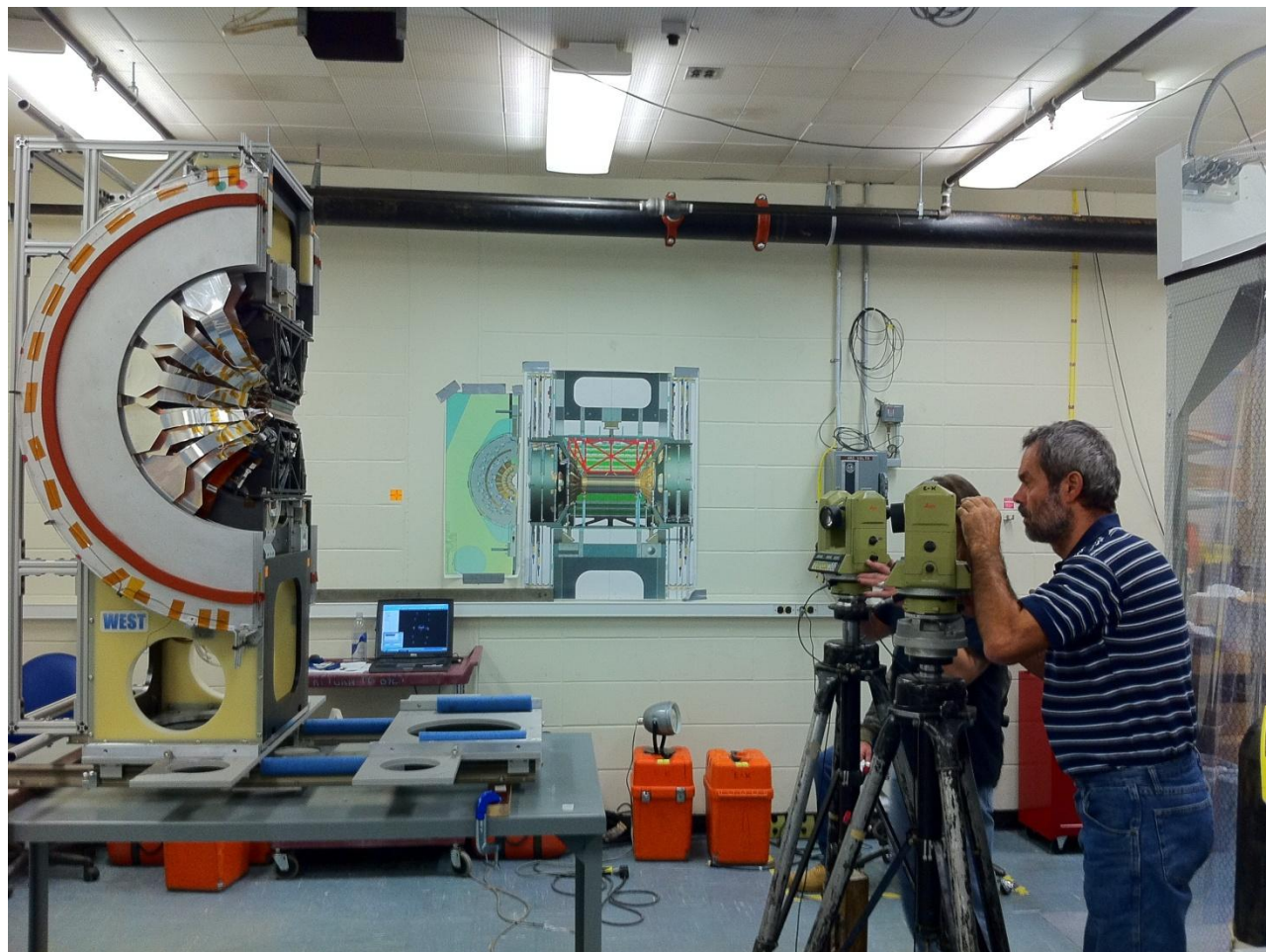
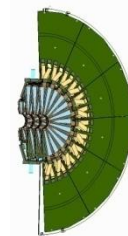
# Metrology, FVTX wedge disk:



One of 6 -100. micron cross-hair targets on Silicon wedge sensor used to verify relationship of sensors on a disk to <10. microns

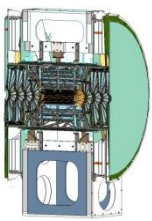


# Metrology, Half VTX assembly:

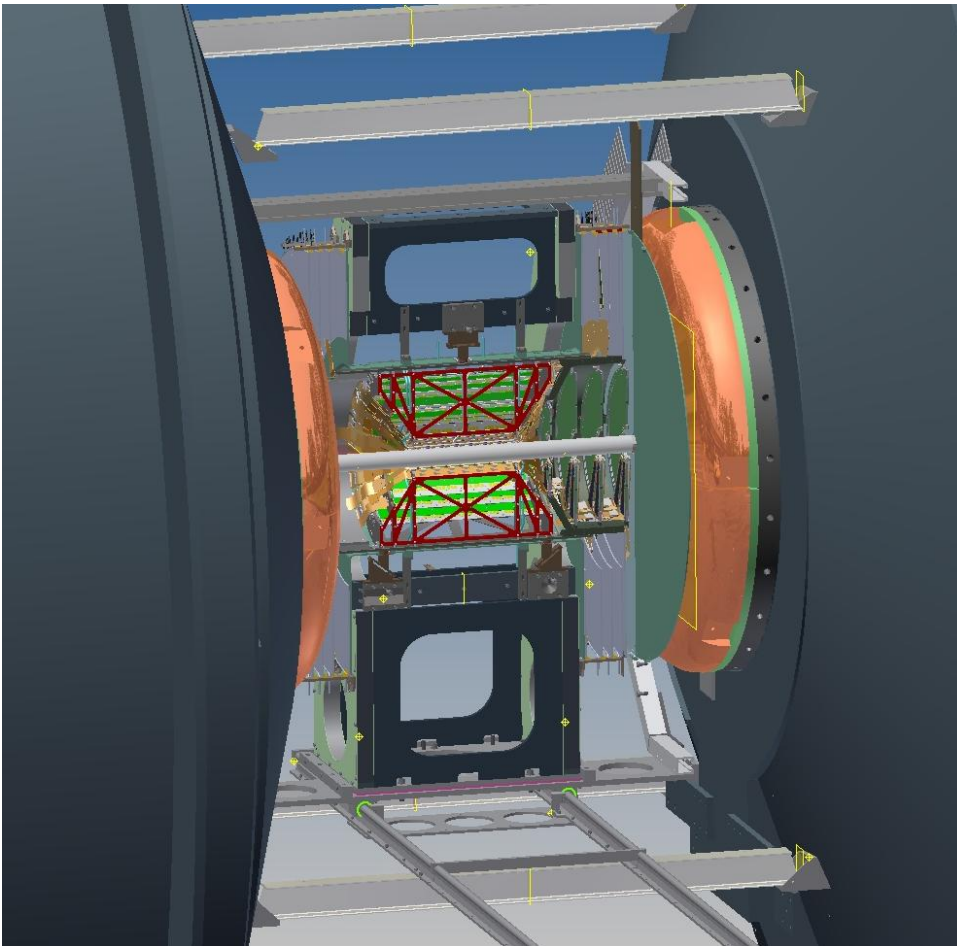
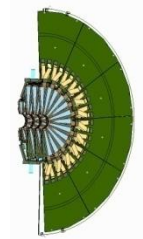


Half VTX assembly being optically surveyed: all ladders to global monuments in assembly. These will again be surveyed in relationship to monuments in the PHENIX hall. Expected detector positioning will be known to  $\sim 50$  microns in the hall.

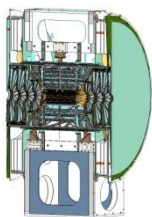




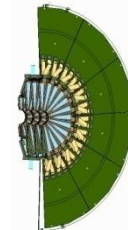
# CAD vs. As-Built:



Demonstration of importance of constructing an accurate CAD model of experimental assemblies, installation of VTX proceeded just as modeled.



# VTX & FVTX collaboration institutions:



- Brookhaven National Laboratory
- Columbia University
- Ecole-Polytechnique
- Iowa State University
- Kyoto University
- Los Alamos National Laboratory
- New Mexico State University
- Oak Ridge National Laboratory
- RIKEN
- Riken-Brookhaven Research Center
- Stony Brook University
- University of New Mexico